Duke Energy Emerging Technology Office

Lesson Learned from Duke Energy's Mount Holly Microgrid Test Site

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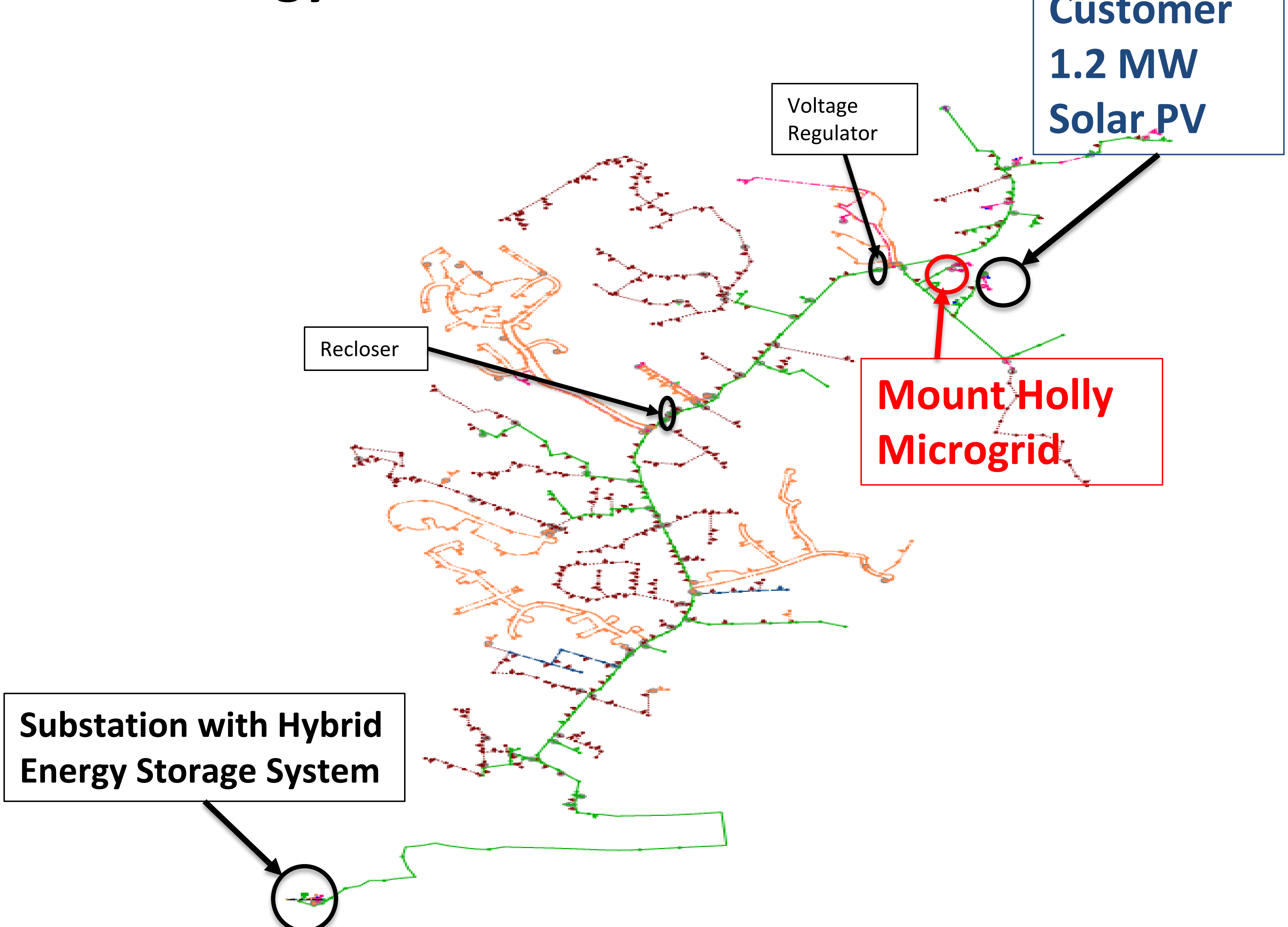
Duke Energy DER Pilot Feeder

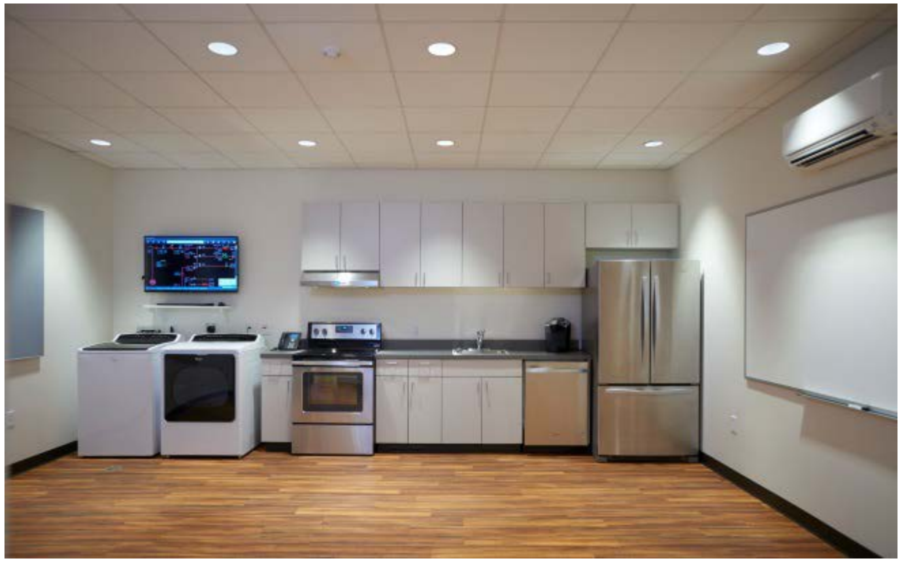


Mount Holly – Videos

Mount Holly Microgrid Components, Cont.

External view of Envision Room

EV Carport with Rooftop Solar PV

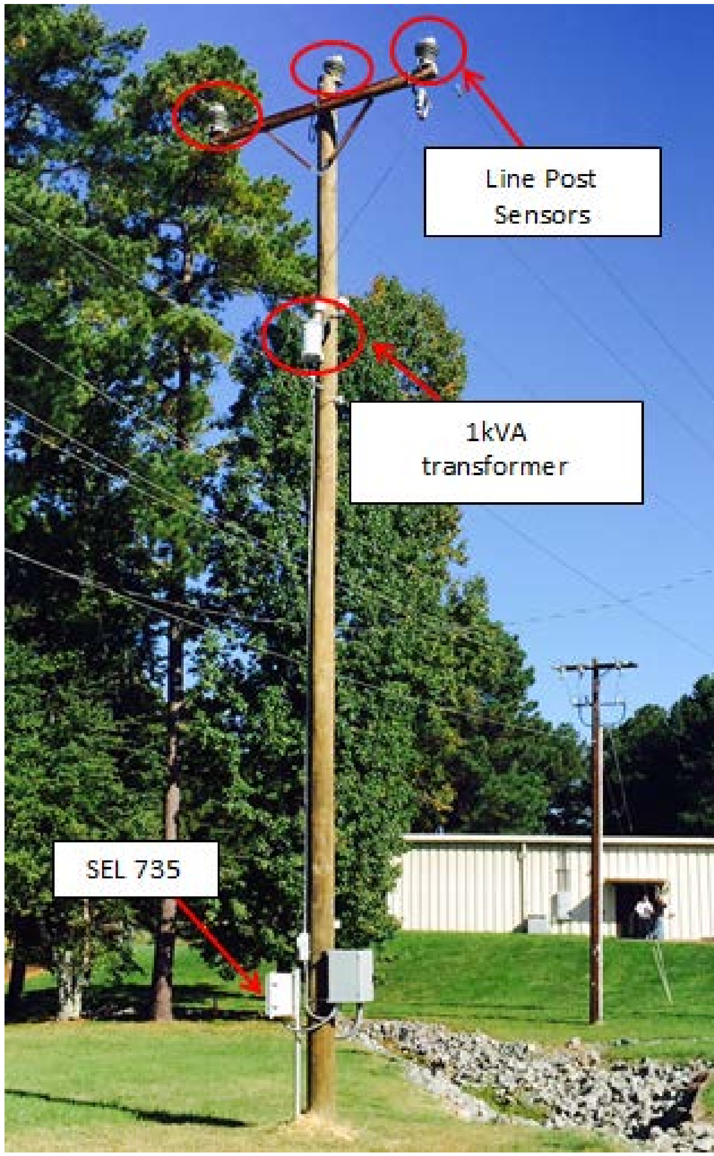


Internal view of Envision Room

EV Charging Station Inside Lab

Mount Holly – Home Battery Energy Storage Solutions

Microgrid Lessons Learned #1 – Sensor Accuracy



R

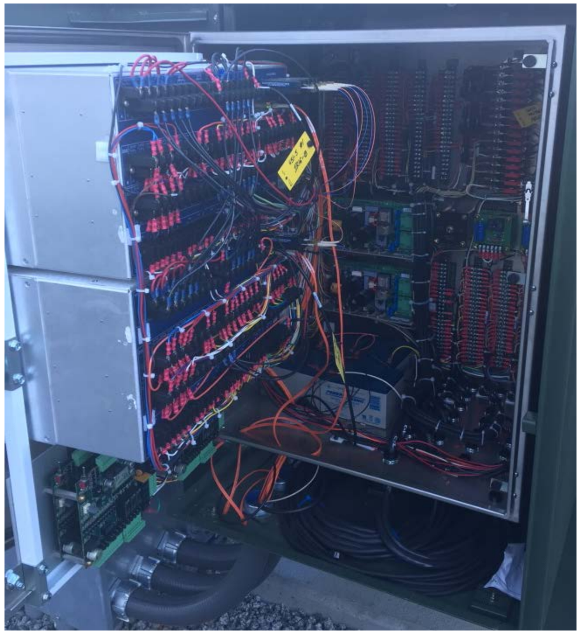
1. Voltage
2. Voltage Angle
3. Frequency

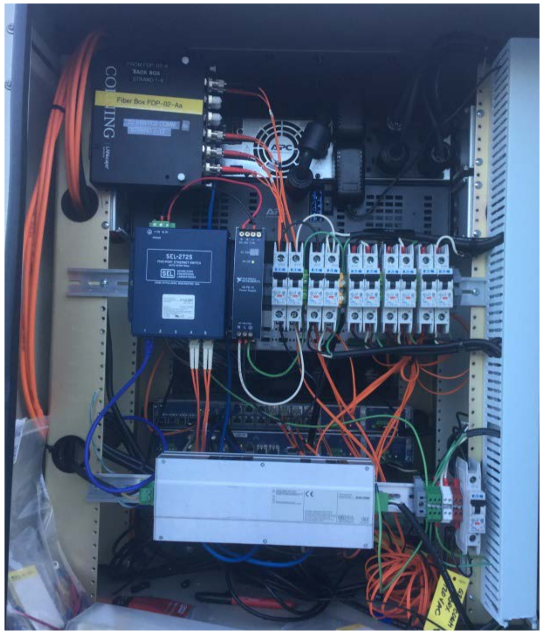
Microgrid Lessons Learned Con't

- #2: Integration of Disparate Assets
  - Successful FAT of equipment doesn't entail system acceptance with DERs
  - Standard product settings might not to be desired configuration
  - New control schemes within microgrid will need further refinement

Microgrid Lessons Learned Con't

- #3: Field Commissioning Coordination
  - Variety of assets with different time lines on drawings and installation
  - Different connectivity diagrams and associated skillsets by voltage levels
    - Power delivery engineers handle drawings for 12KV primary
    - Electricians handle 277/480V and 120/208/240V secondary levels
    - IT staff used for 12/24/48VDC wiring of telecommunications & UPS.





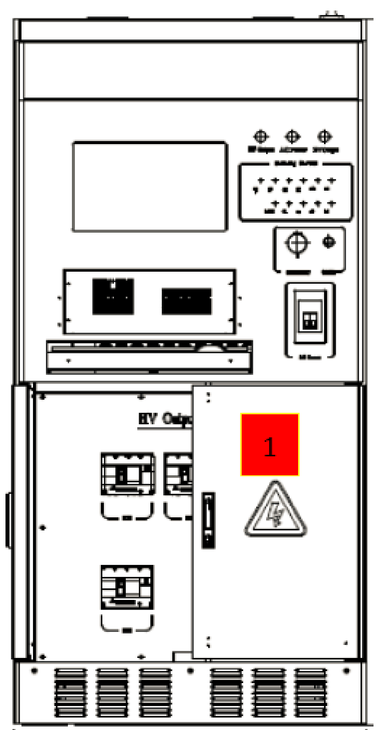
Microgrid Lessons Learned Con't

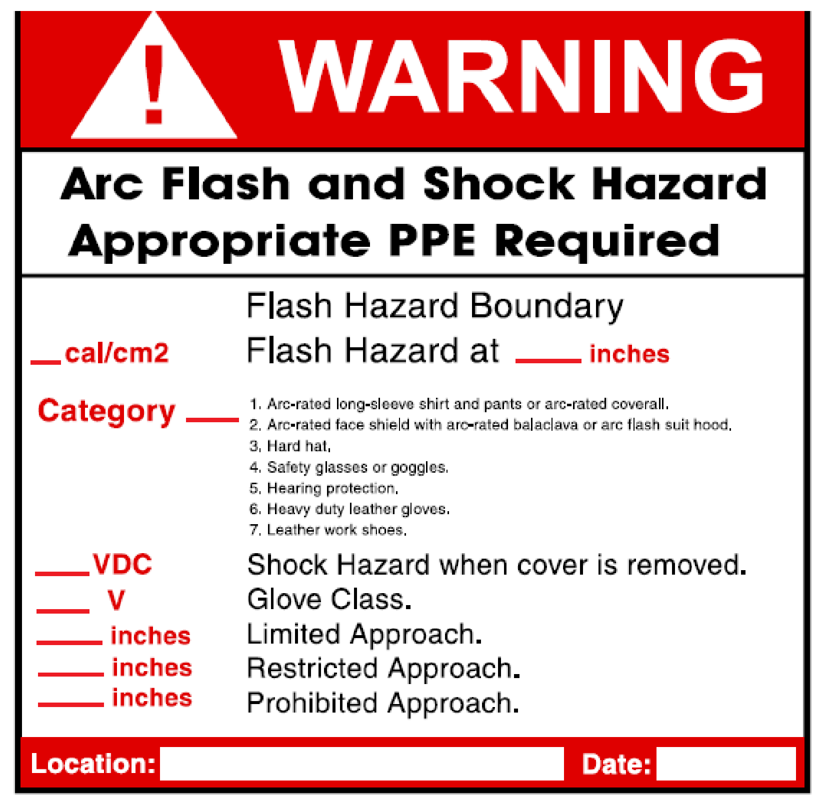
- #4: Understanding of Load Diversity
  - Minimum, Maximum, and Average Loads
  - Proper distributed generation / storage mix
  - Optimal DER capacity ratings for the desired microgrid objective

- #5: Supplemental Engineering Studies
  - DER's connected to 12.47kV system and 480/277V Y-grounded system.
  - Microgrid Loads are 120/240V and 277/480V
  - Most power systems planning tools don't model secondary side
    - Steady-state modeling: Only grid-connected mode
    - Short-circuit studies: Fault transients, trip settings

Microgrid Lessons Learned Con't

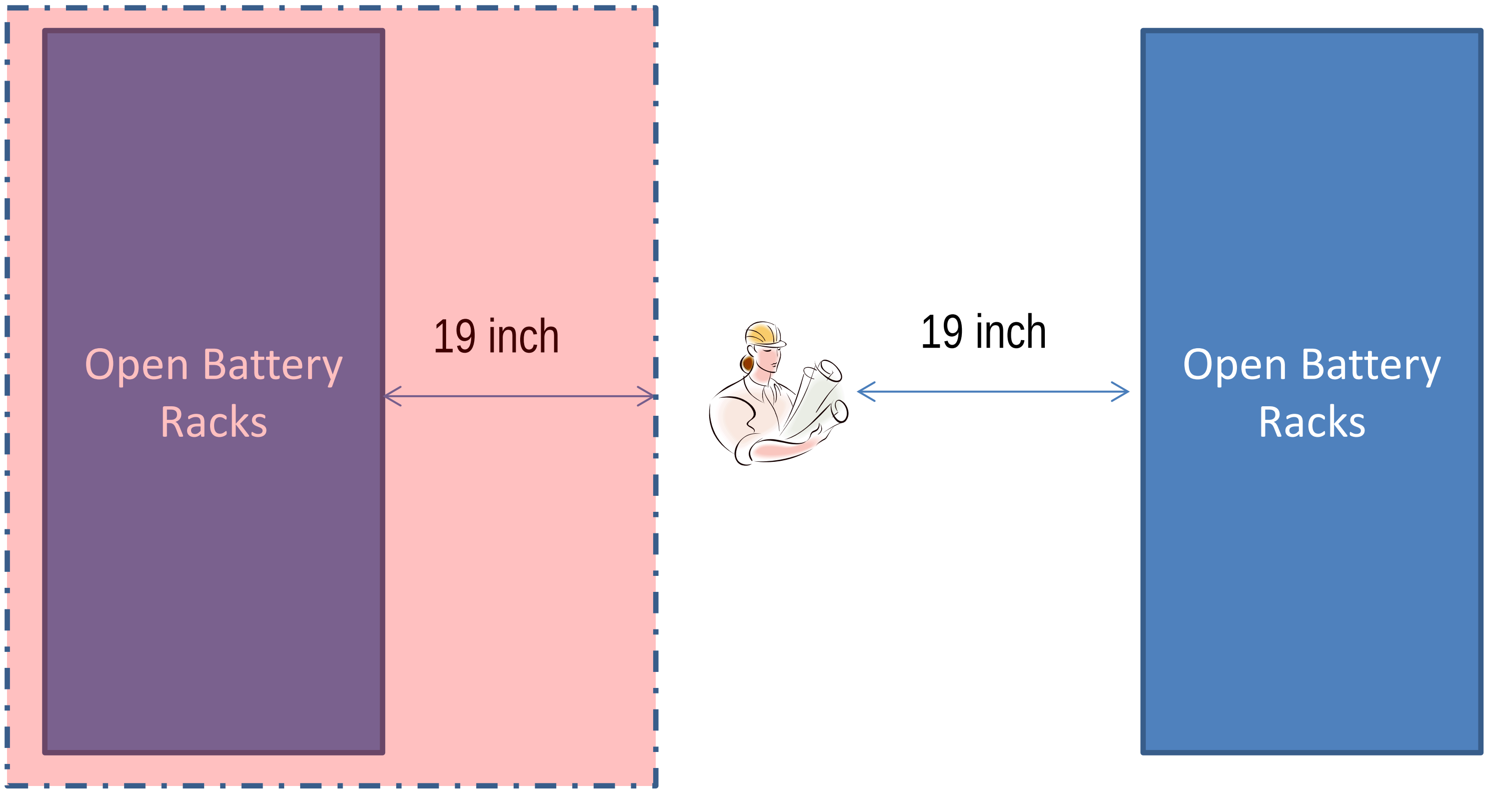
- #6: Safety – DC Arc Flash Analysis
  - BESS and PV systems rarely come with DC ARC-FLASH analysis
  - This analysis is a MUST before the any commissioning work has begun
  - NFPA70E for calculations





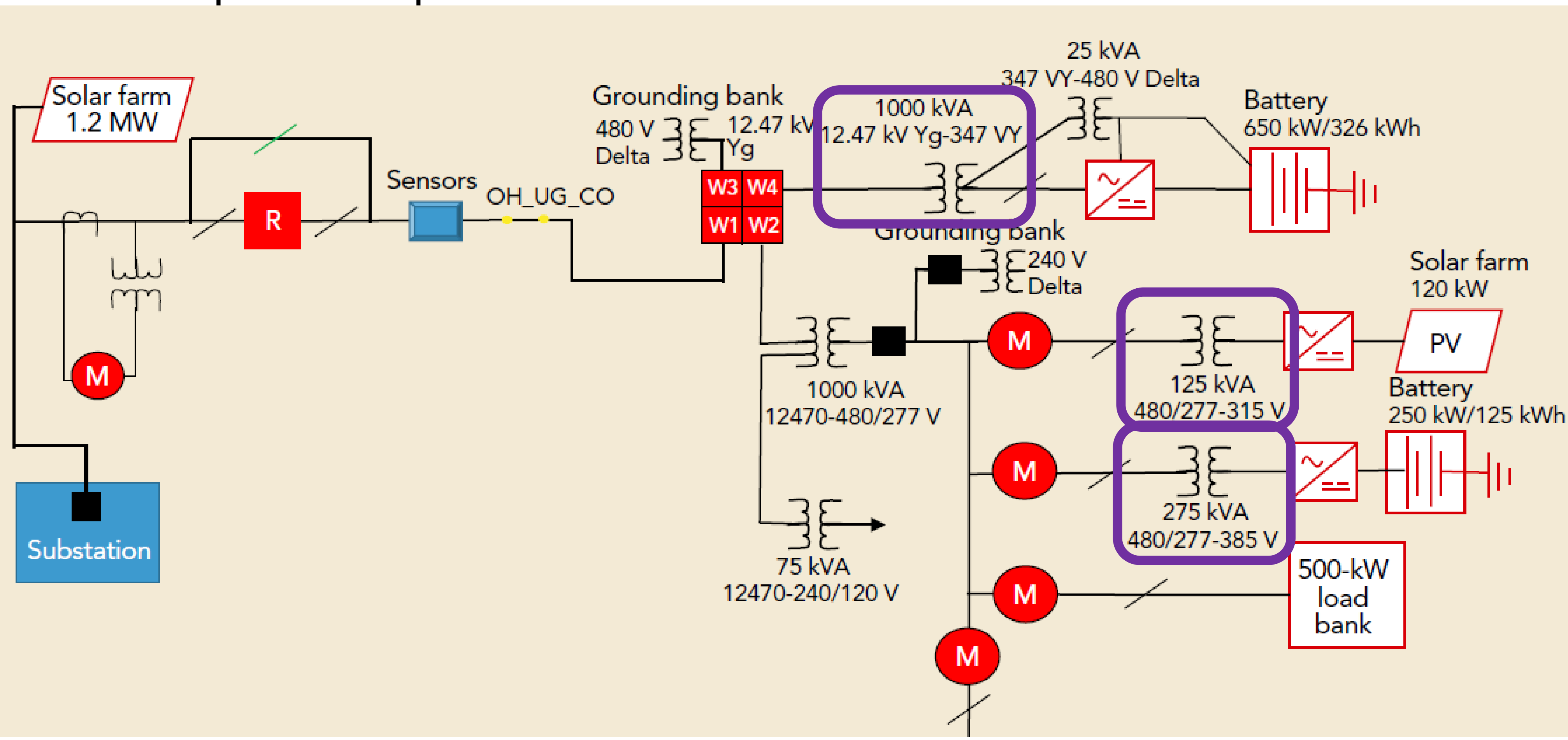
Microgrid Lessons Learned Con't

- #6: Safety – BESS Design
- Some battery energy storage systems come in open racks (i.e. no doors that cover the batteries)
- The distance between the battery racks sometimes is not enough for a person working on it to be 19 inches away from both sides



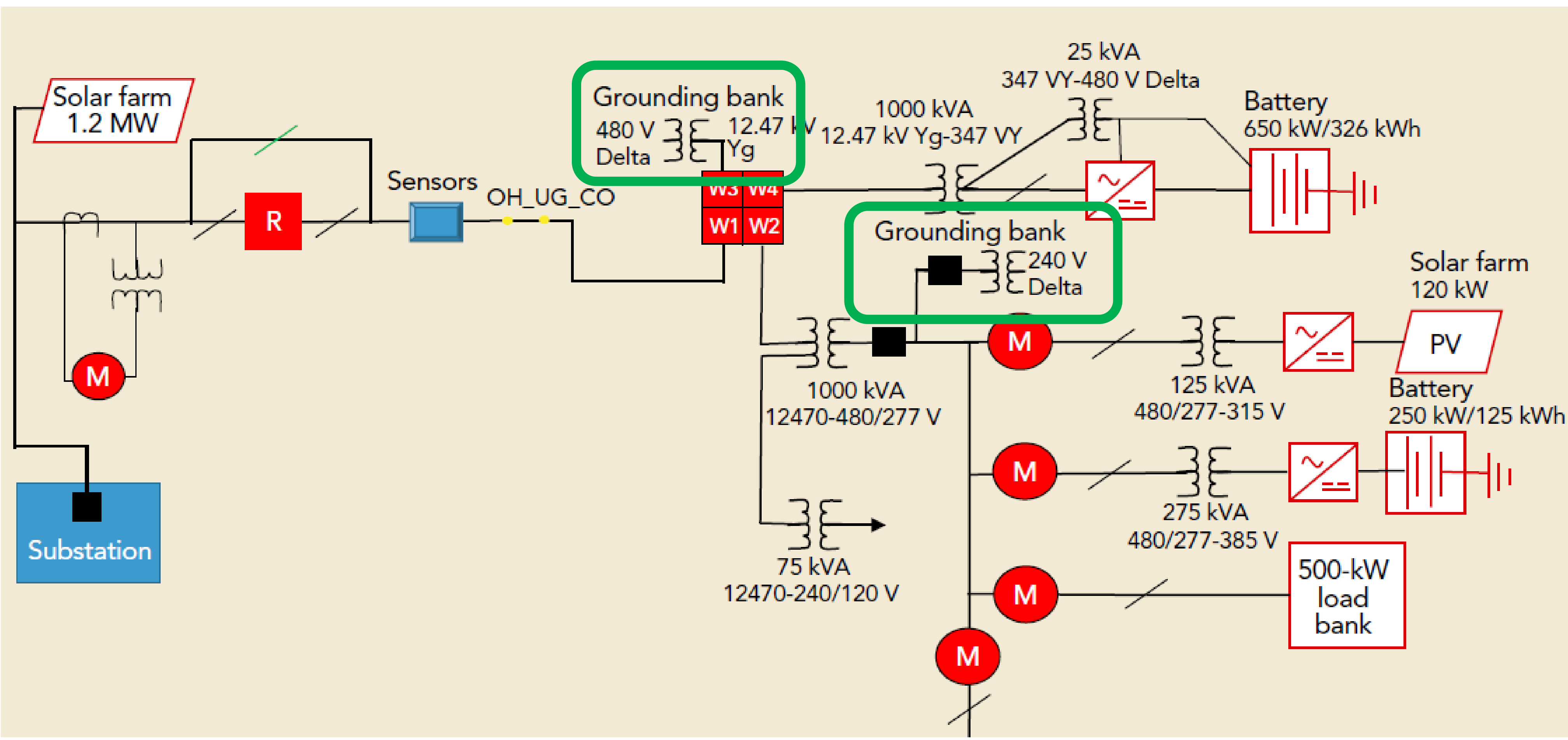
Microgrid Lessons Learned Con't

- #8: Inverter Transformers
  - **Y-grounded-Y(floating)** vs. **Y-grounded-Delta**
  - AC voltage levels not common (315VAC, 347VAC, 380VAC), which requires unique transformers



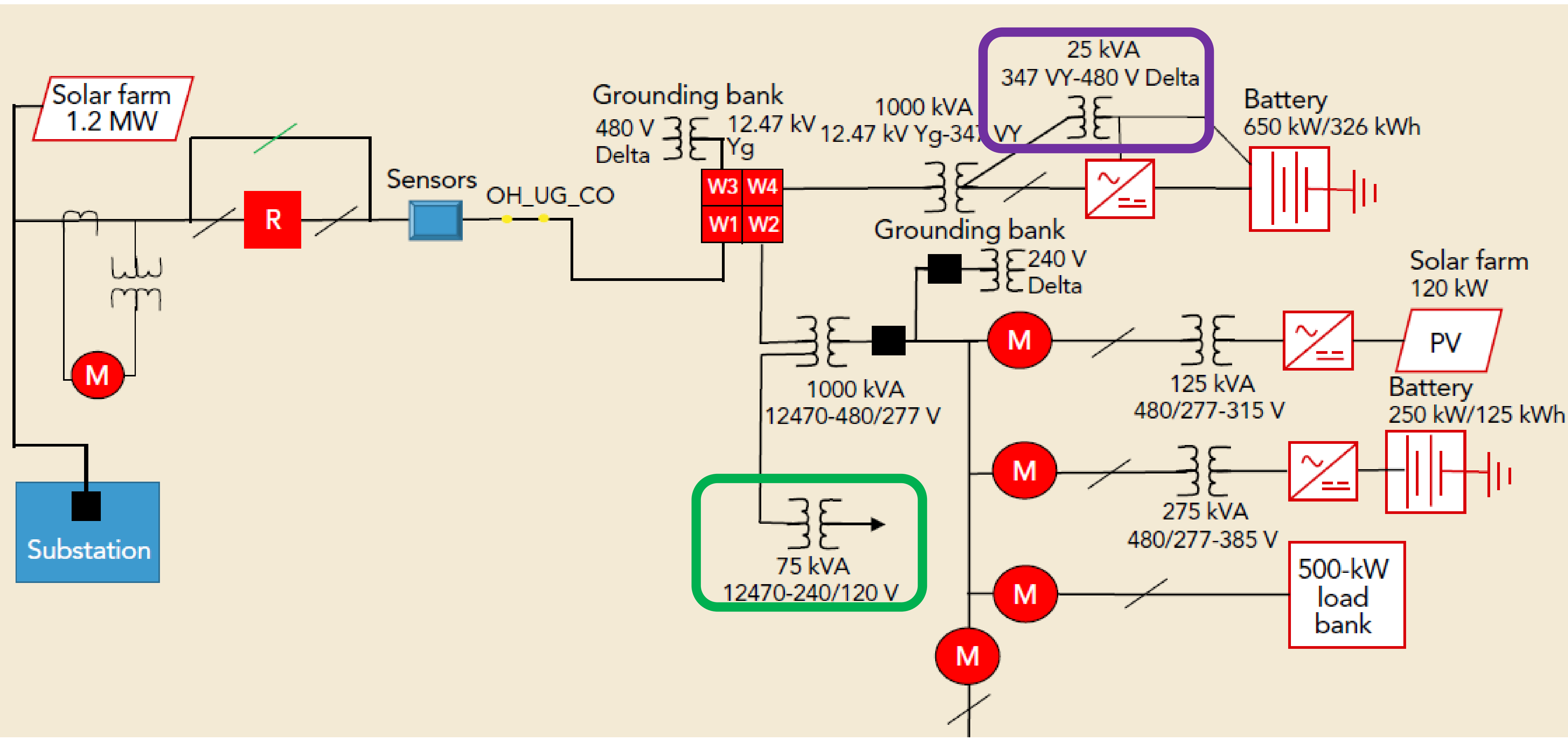
Microgrid Lessons Learned Con't

- #9: Grounding Considerations for Protection
  - **Grid-Connected mode** vs. **Island-mode** Transformer Configurations
  - Yg – Delta Transformer Grounding Bank vs. Zig-Zag Transformer



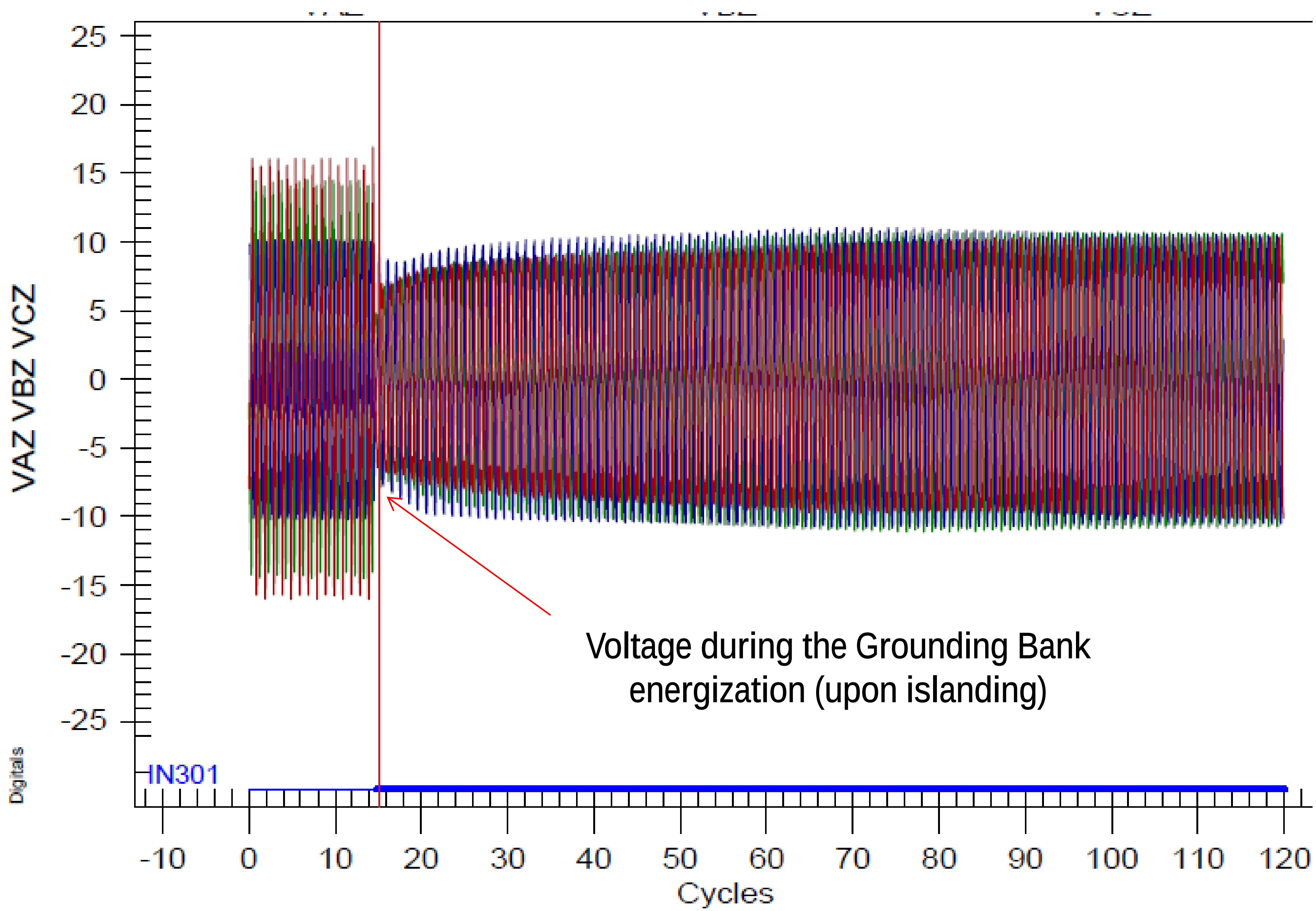
Microgrid Lessons Learned Con't

- #10: Auxiliary Transformer
  - 25kVA 347V Y(Floating) – 480VAC Delta Aux. Transformer
  - 75kVA 12.47kV – 120/240VAC Aux. Transformer



Microgrid Lessons Learned Con't

- #11: Relay Settings - 27/59/81 (Grounding Bank Energized)



Microgrid Lessons Learned Con't

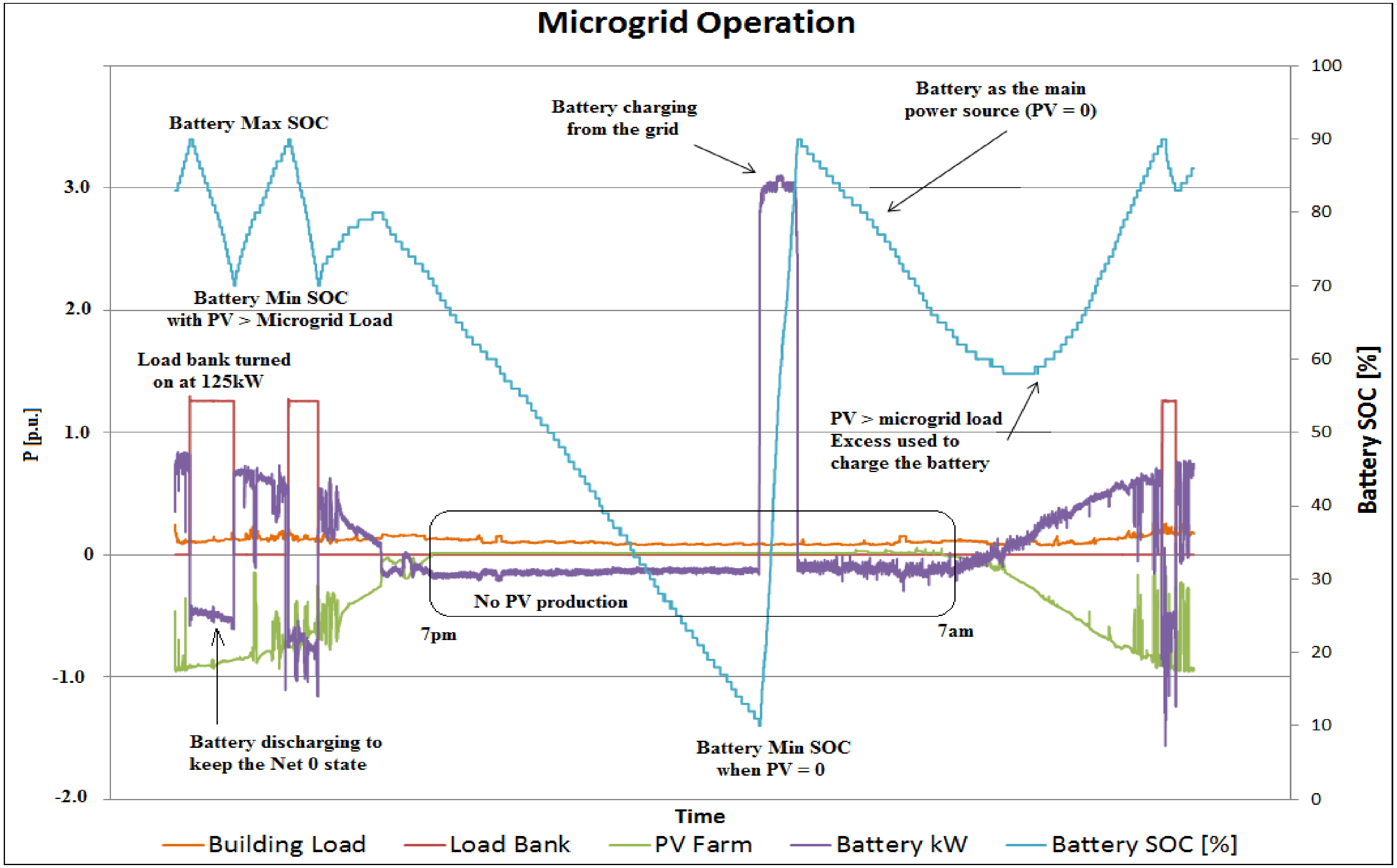
- #12: Battery Challenges
  - Low-inertia microgrids are a function of Battery System's reliability
  - Thermal management is most important aspect of Li-Ion batteries
  - HVAC system is the "Achilles Heal" of battery storage systems
  - Auxiliary power can be 10-20% of battery rating (HVAC, fire suppression system, controls, lighting, etc…)
- #13: Backup Power
  - Three common solutions:
    - Connect the DER to the same feeder as the main feed
    - Run a generator
    - Internal UPS

Microgrid Lessons Learned Con't

- #14: Battery Controller
  - CanBus (internal) & Modbus (battery to inverter)
  - Challenge – user only receives the battery data from inverter, which might be limited
  - Solution – battery controller that can speak to two masters (inverter for control, and head-end system for asset health monitoring)
  - Typical connection is Ethernet port
  - Change it to Fiber/Ethernet switch and ensure that it is on UPS
  - Internal battery health condition monitor typically does not exist
  - Currently working on defining of what this monitor functionality should be
  - Two approaches: traffic light vs. probability of failure

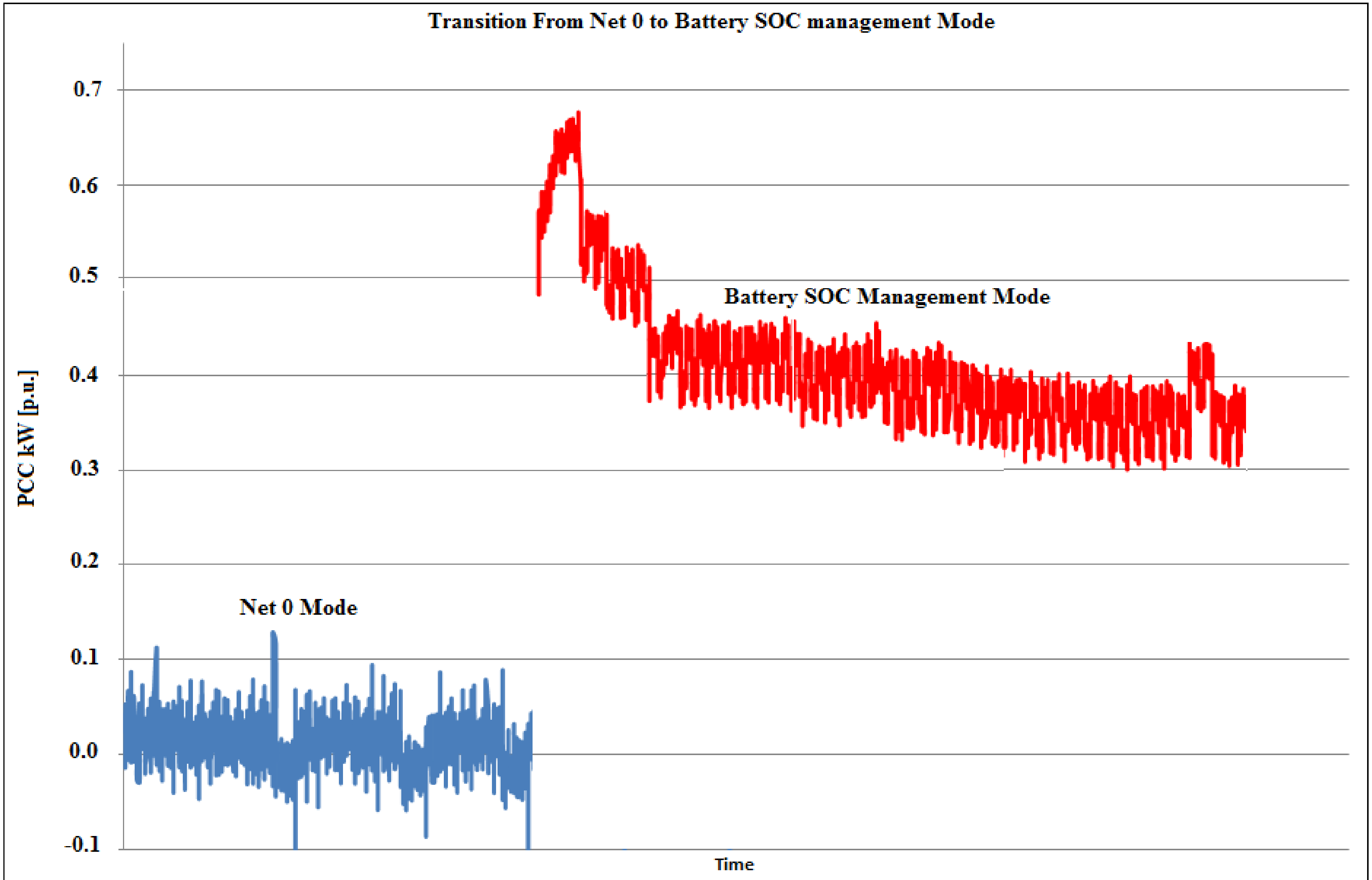
Microgrid Lessons Learned Con't

- #15: Backfeed Restrictions
  - Interconnection process might take a long time and the interconnection agreement might not allow DER export onto grid



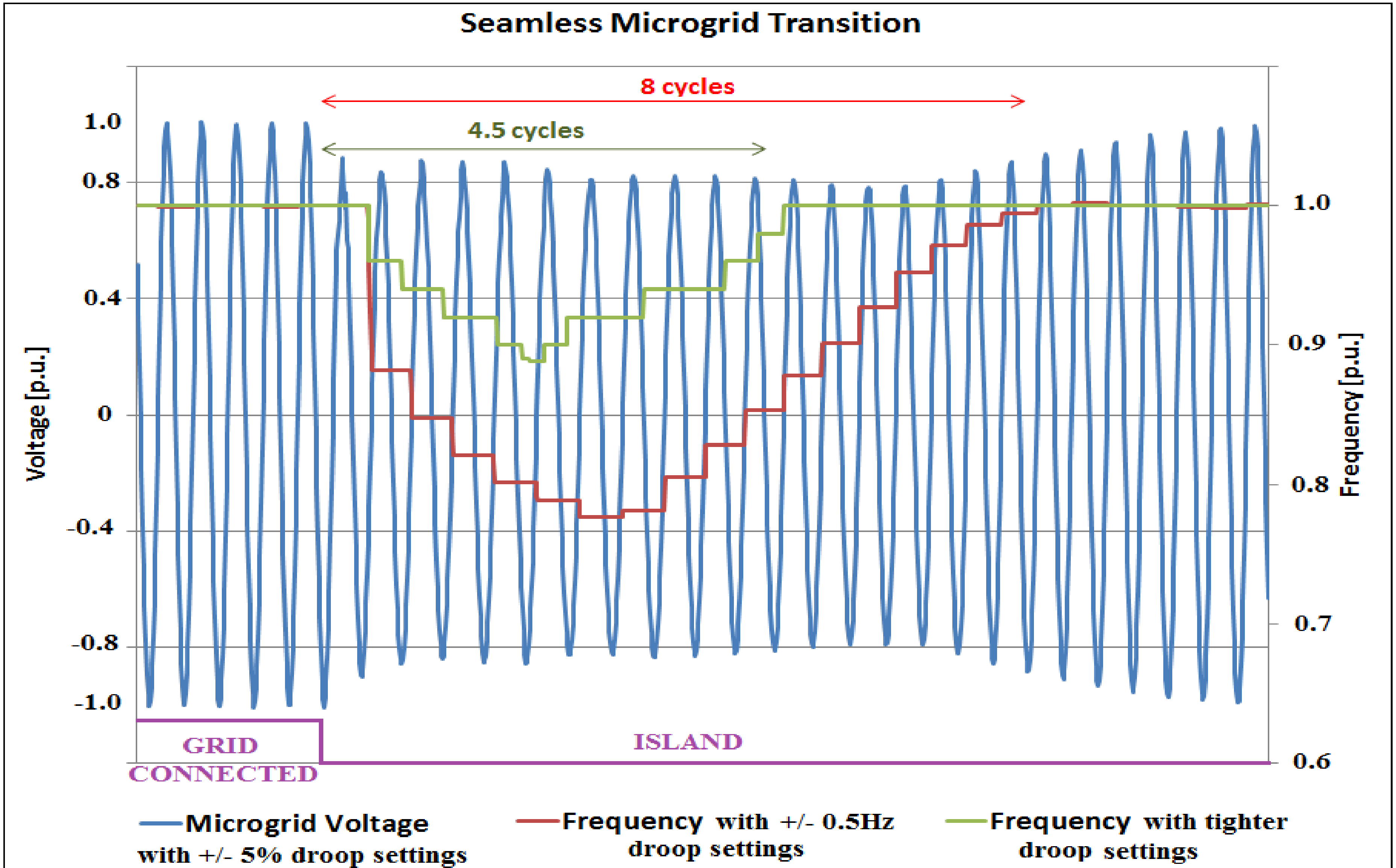
Microgrid Lessons Learned Con't

- #16: Net-0 vs. Battery SOC Operating Mode



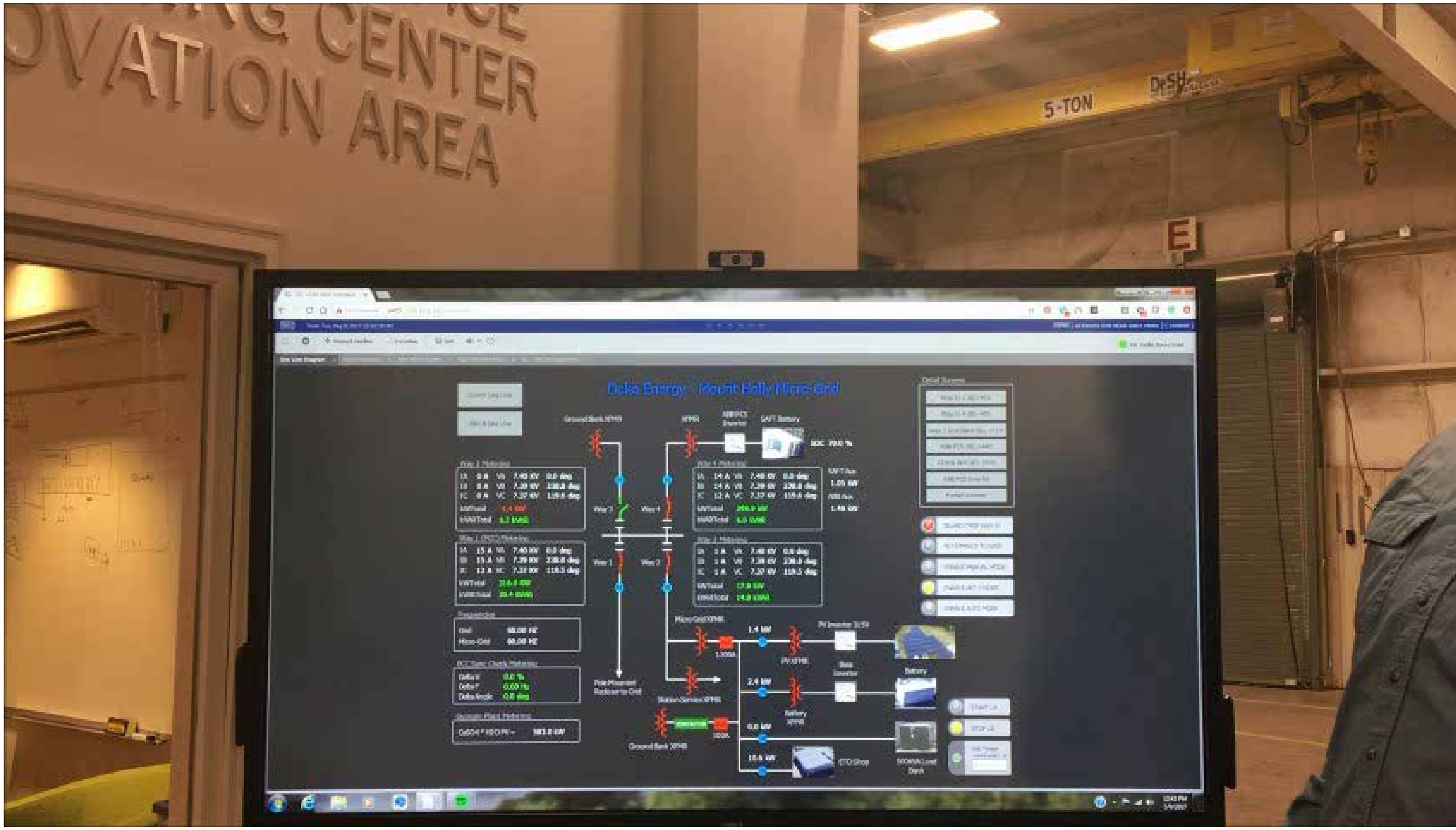
Microgrid Lessons Learned Con't

- #17: Seamless Microgrid Transition



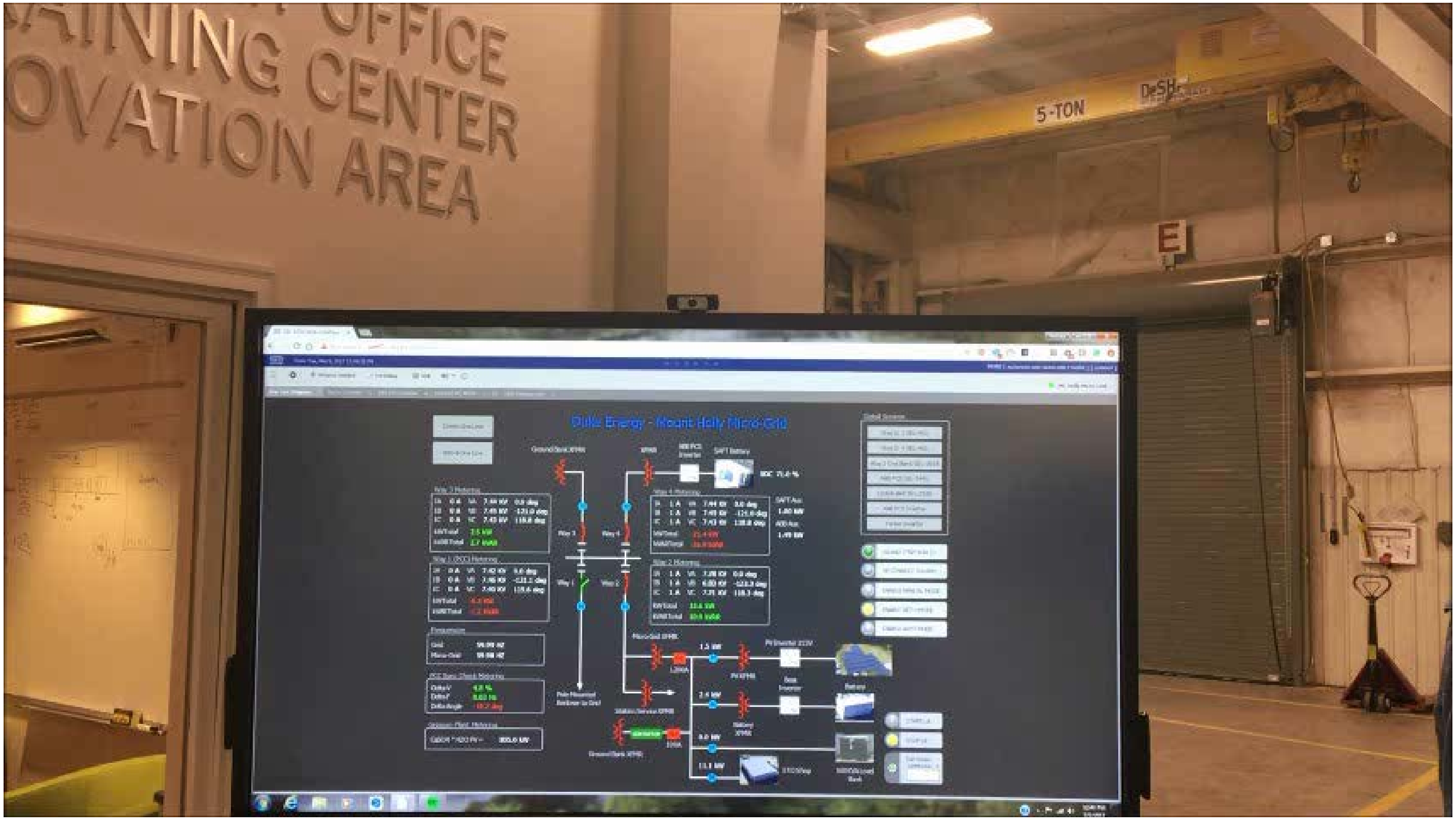
Mount Holly – Videos

Islanding



Mount Holly – Videos

Grid Re-connect



Microgrid Lessons Learned Con't

- #18: Seamless Microgrid Transition: Why does it work?

1. Generation/load ratio is large
2. Load composition and inertia are constant
3. We intentionally switch inverter operational mode when the microgrid islands
4. The grid source is very strong and constant
5. Advanced inverter that is tuned properly

Note: more diverse set of loads with varying load composition and inertia might present a closed loop tuning issue where the system time constant changes and therefore gov/exc/inverter tuning must adapt.

OpenFMB use-cases at Rankin/Mount Holly Sites

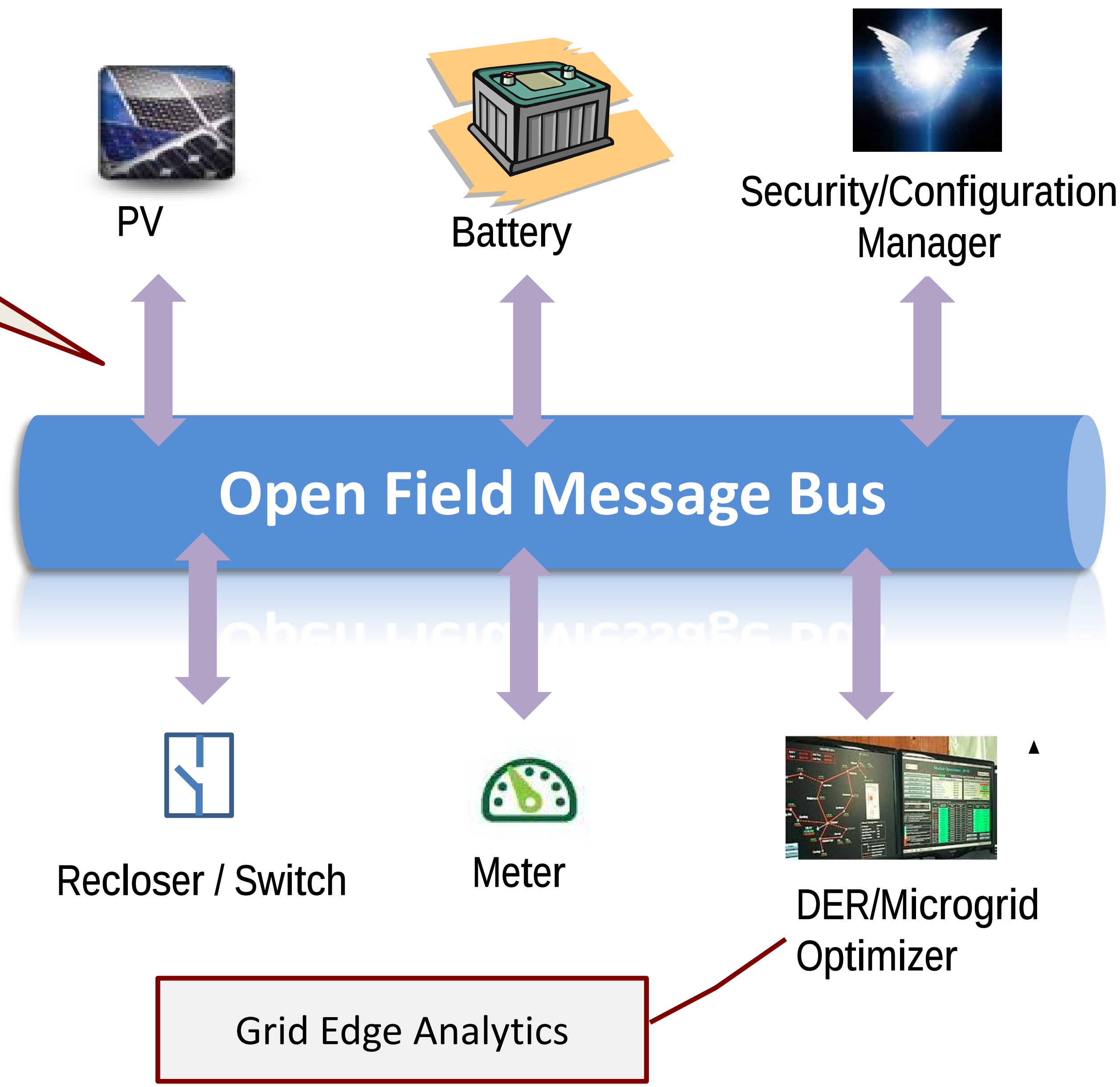
- Microgrid Management (2015)
  - Circuit Segment Optimization
  - Unscheduled Islanding Transition
  - Grid-to-Island Reconnection
- DER Circuit Segment Management (2016)
  - Primary Scenario: Voltage, Frequency, Power Factor support
    - DER Point of Interconnection (POI) Coordination
    - Point of Common Coupling (PCC) Coordination with Microgrid Use-cases
  - Secondary Extensions:
    - Solar Smoothing: Battery Optimization
    - Volt-Var Management: Power Factor Optimization
    - Peak Demand: Shaving/Shifting
  - Tertiary Extensions:
    - Distribution Transfer-Trip
    - Anti-Islanding: Inadvertent Island Detection

OpenFMB Operation: Federated Deterministic Exchanges

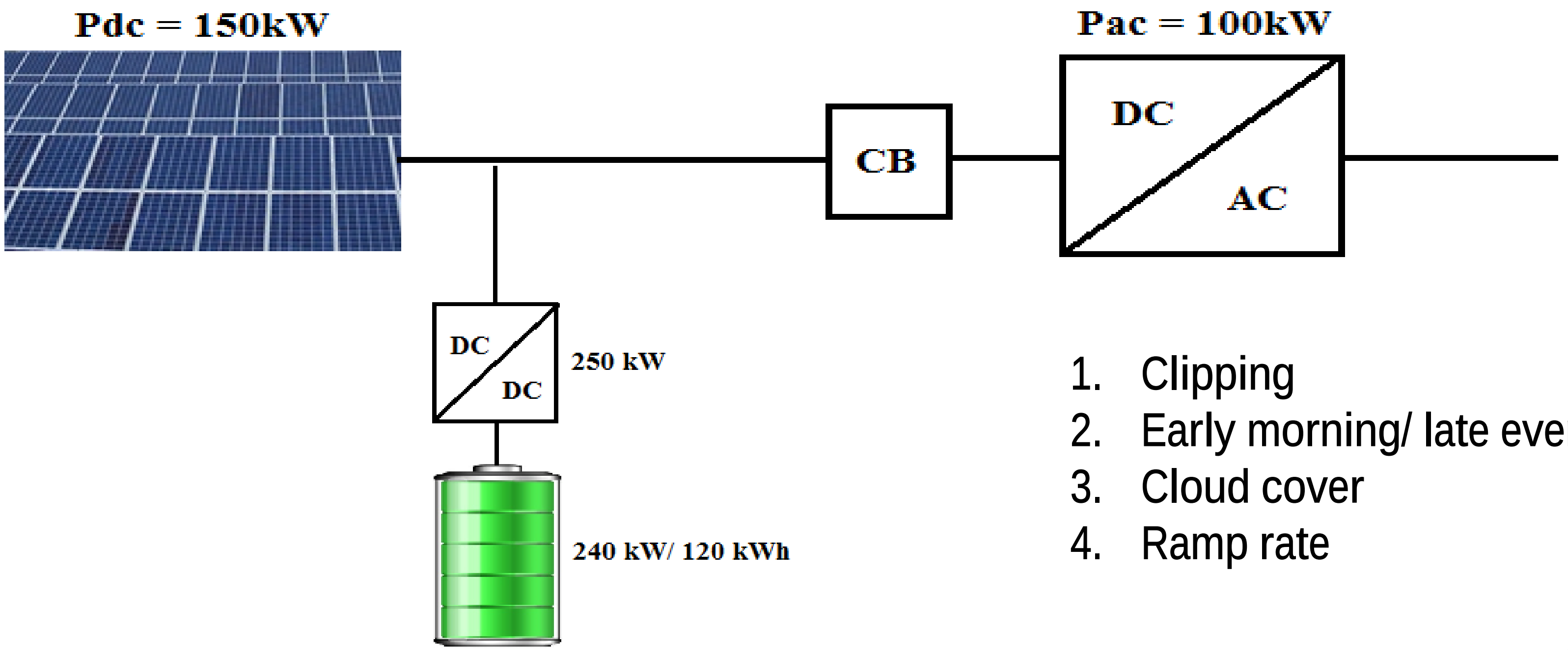
- Periodic Readings - Pub every few secs or near-real-time
- Data-Driven Events – on status change in near-real-time

Readings
KW: A/B/C
KVAR: A/B/C
V: A/B/C
I: A/B/C
Phase Angle: A/B/C
KWh
TimeStamp
SOC

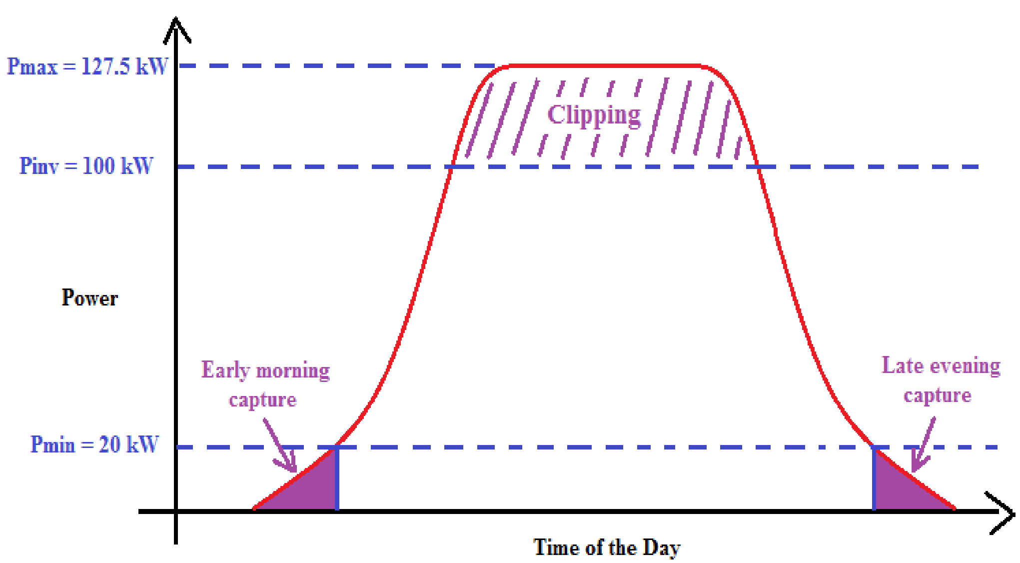
Status, Events, Alarms, & Control
Trip / Open
TimeStamp

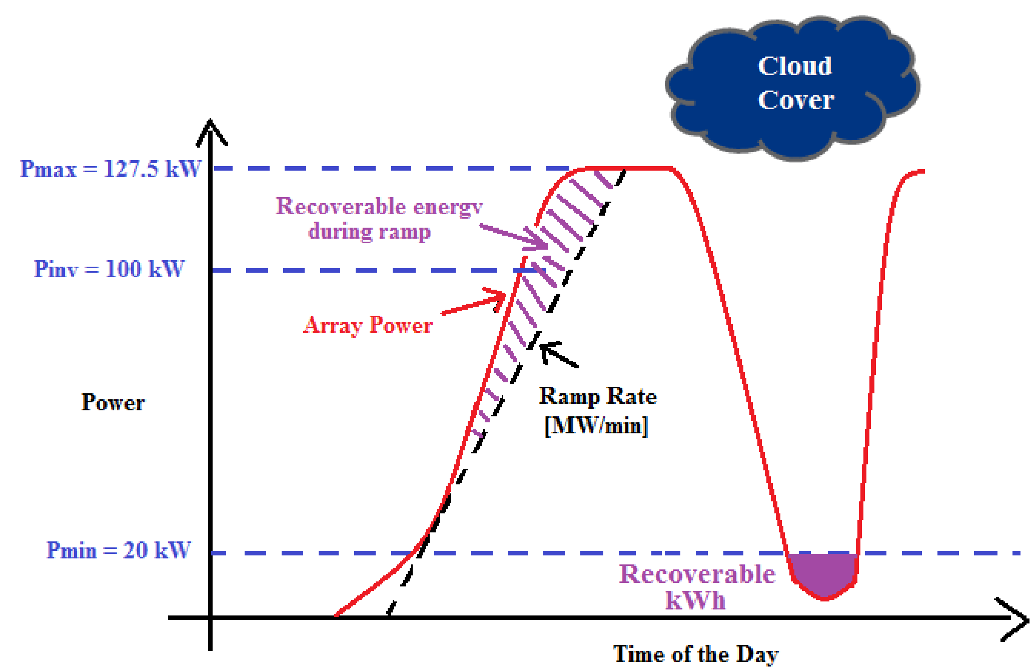


Next Steps – Battery Integration with PV Inverter



1. Clipping
2. Early morning/ late evening
3. Cloud cover
4. Ramp rate





Thank You!

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